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AN IMPROVED HEATING AND CIRCULATING SYSTEM TO USE IN DOUBLE-VARIATION PROCEDURE*

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ABSTRACT

A small heating unit and circulating system has been constructed for use with the double-variation procedure for refractive index determination. It furnishes water, thermostatically controlled to any desired temperature, to the microscope stage and refractometer, and can be used when only a limited supply of hot water is available. The use of water free from air prevents the formation of bubbles in the water cell of the microscope stage.

INTRODUCTION

Following Emmons'[1] specifications for the equipment necessary for using the double variation procedure for refractive index determination, the apparatus was obtained for installation in the Harvard Mineralogical Laboratories. Since there was no source of continuous hot water in the building, a fifteen-gallon electric hot water heater was purchased. When the equipment was eventually put in working order and used continuously for an hour, it was discovered that the hot water supply was inadequate to maintain a temperature above 30° C. It was, thus, necessary to either buy a much larger heater or devise a system in which a small volume of hot water could be circulated. The latter course was decided upon and the heating and circulating system described herein was the result.

It seemed desirable to incorporate in any unit the following features: (1) It should be of small volume so that the time required to change the temperature of the system would be reduced to a minimum, and so that only a small amount of additional heat would be required to maintain a required temperature. (2) It should be possible to vary the temperature either upward or downward easily and rapidly. (3) It should be controlled thermostatically so that the temperature could be brought to any pre-

* Contribution from the Department of Mineralogy and Petrography, Harvard University, No. 284.

[1] Emmons, R. C., *Am. Mineral.*, **14**, 415 (1929).
Emmons, R. C., The Universal Stage: *Geol. Soc. Am.*, Memoir **8**, Chap. 5 (1943).

determined value and maintained there indefinitely. (4) The water in the circulating system should be distilled to prevent deposition on the glass plates of the water cell. It should be boiled to drive off the air, preventing the accumulation of air bubbles.

Heating and Cooling Unit

After several changes in design, the unit illustrated diagrammatically in Fig. 1 was constructed. It embodies most of the required desirable features. As can be seen from the diagram it is comparatively simple in design and construction. It consists of a brass tube 4 inches in diameter and $4\frac{1}{2}$ inches long with brass plates soldered at the ends. The parts shown in Fig. 1 are as follows:

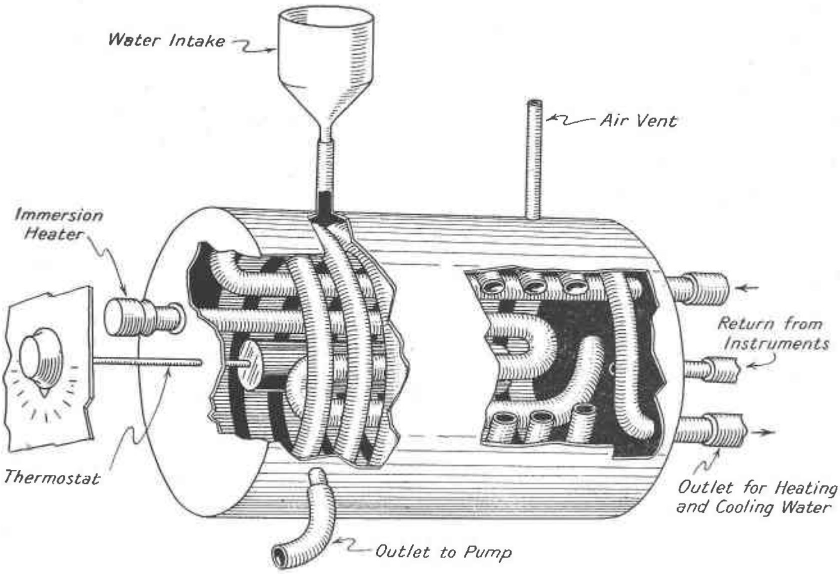

Fig. 1. Schematic diagram of heating and cooling unit.

At the center of the cylinder is a thermostat with a control rod extending through the left end. By turning the knob the thermostat can be adjusted for any desired temperature. A 150 w. immersion heater with its two leads extending from the tube is controlled by the thermostat. About 10 feet of $\frac{3}{8}$ inch copper tubing is coiled about the inside of the cylinder with the ends extending from the right end. The upper end is connected by rubber tubing to a water supply which can at will be either hot or cold. Rubber tubing from the lower end goes to waste.

From the opening, "outlet to pump," water leaves the heating unit to circulate through the apparatus and is returned to the heater at "return from instruments." At the top of the cylinder the funnel tube is for introducing water into the system, and the other tube is a vent for the escape of air. Both tubes are 3 inches long to allow for the expansion and contraction of the water.

Circulation of Water

Several small pumps of standard manufacture were obtained and used to pump the water from the heating unit, circulate it through the microscope stage and refractometer, and return it to the heating unit. The one illustrated in Fig. 2 proved to be the most satisfactory. It is a diaphragm pump[2] designed for circulating small volumes of water. Although its capacity is small, the volume of the system is so limited (approx. 1,000 cc.) that it will circulate the water about four times a minute. This is wholly adequate for keeping the instruments at a constant temperature. Both the heating unit and pump are inclosed in a box $12'' \times 10'' \times 6''$. The thermostat knob and switches for controlling the heater and pump are at the front; the water connections are at the back.

The equipment as arranged in Fig. 3 has three dial thermometers. One of these records the temperature of the water as it leaves the circulating pump. After passing this thermometer, the stream is divided, one going to the water cell of the microscope stage and the other to the refractometer. The other thermometers record separately the temperatures of the water after it leaves these two instruments and before it returns to the heating unit. Having the insturments in parallel rather than in series enables them to come to equilibrium sooner.

When all proper connections are made, distilled water that has been boiled to drive off the air is poured through the funnel tube into the circulating system. With the pump in operation the water quickly displaces the air and should be permitted to rise a short distance above the top of the heating unit. As evaporation takes place, more water should be added to maintain this approximate level. If this is done, the free water surface is extremely small and the chances of adsorbing air are reduced to a minimum.

Operation of the Heating Unit

In making a refractive index determination by the double variation procedure, the first measurements can be made at room temperature, which might be 23° C. If one then wishes to elevate the temperature to 35° C., the circulating pump and the immersion heater should be turned

[2] Marco Water Pump, manufactured by Marco Products, Bloomfield, N. J.

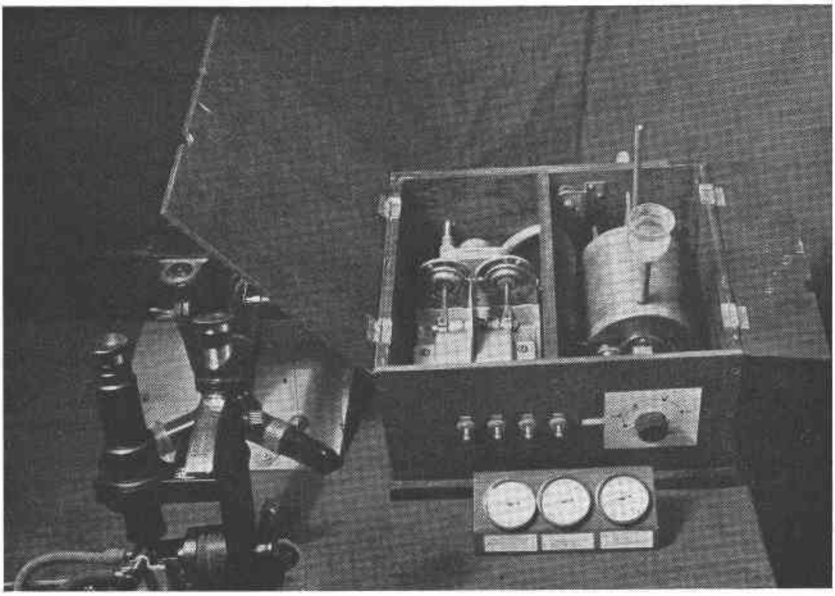

FIG. 2. Heating unit and pump.

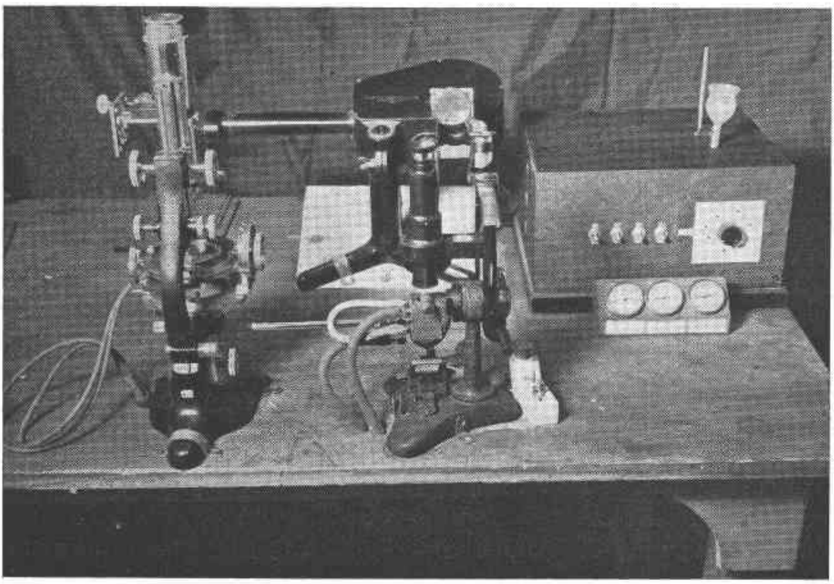

FIG. 3. Relation of heating unit to microscope and refractometer.

on, and the thermostat set for 35 °C. With the 150 w. immersion heater the time necessary to raise the system the required 12° would be about eight minutes. However, if hot water is available, it should be passed through the copper coil which is completely independent of the circulating system. A limited supply of hot water if at a temperature of 70° C. will in less than a minute raise the temperature of the system close to the desired 35° C. One should watch closely the thermometer recording the temperature of the water as it leaves the pump so that when it approaches the required temperature, the hot water can be turned off. The immersion heater will then quickly add the necessary degree or two and from then on hold it at the predetermined temperature. A pilot light indicates when the immersion heater is turned on and off by the thermostat.

If there is no external source of hot water, a large immersion heater can be used to speed the heating.

When one wishes to go from a high to lower temperature, the thermostat is reset and cold water is run through the copper coil. To obtain temperatures between the temperature of the tap water and the room, a small amount of cold water should be run continuously through the copper coil. This cooling effect will be offset by the immersion heater so that the required temperature can be maintained.

Conclusions

The heating and circulating system as described has been in use in the Harvard Mineralogical Laboratories for over five years. During that time it has given excellent service and none of the parts has had to be repaired or replaced.

Although the construction was undertaken to overcome an inadequate supply of hot water, the system's advantages extend beyond this. The fact that the water is air free is in itself sufficient reason for its use, for one is not troubled with annoying air bubbles which otherwise form in the water cell on the microscope stage. In addition, it is advantageous to know that the temperature will remain constant during a series of measurements and not be subject to variations in the temperature of the hot or cold water sources.

Acknowledgments

A grant from the Permanent Science Fund of the American Academy of Arts and Sciences was made to the writer to further the investigation and construction of a heat and light source to be used in connection with the double variation procedure. This grant is most gratefully acknowledged, but the work is not completed on the light source. It is hoped

that within a few months a light source with a continuous variation of wave length using absorption filters will be available.

Acknowledgment and thanks are due Mr. Donald Henderson for installing and arranging the apparatus as shown in Fig. 3.